US009160075B2

(12) United States Patent
Tsai et al.

(10) Patent No.: US 9,160,075 B2
(45) Date of Patent: Oct. 13, 2015

(54) **MULTI-BAND ANTENNA FOR PORTABLE COMMUNICATION DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 571 days.

(21) Appl. No.: **13/304,722**

(22) Filed: **Nov. 28, 2011**

(65) **Prior Publication Data**

US 2013/0135156 A1 May 30, 2013

(51) **Int. Cl.**

H01Q 5/01	(2006.01)
H01Q 9/42	(2006.01)
H01Q 5/371	(2015.01)
H01Q 1/24	(2006.01)
H01Q 1/48	(2006.01)
H01Q 13/18	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 9/42*** (2013.01); ***H01Q 5/371*** (2013.01); *H01Q 1/243* (2013.01); *H01Q 1/48* (2013.01); *H01Q 13/18* (2013.01)

(58) **Field of Classification Search**

CPC H01Q 5/01
USPC 343/702
See application file for complete search history.

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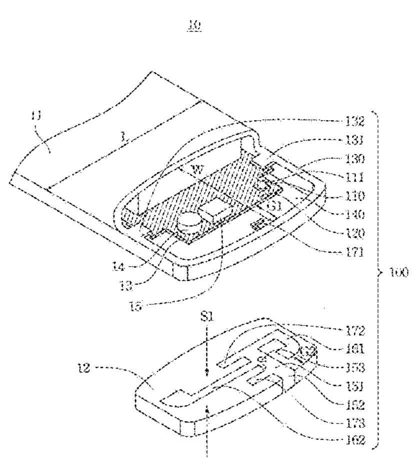
(57) **ABSTRACT**

A multi-band antenna for a portable communication device is disclosed, in which the communication device includes a first housing, a second housing and a substrate. The multi-band antenna includes a feeding portion, a system ground plane, a metal ring, a resonant cavity, a first and a second radiating portion. The system ground plane is disposed on the substrate. The metal ring is connected to the first housing, and forms a space with the first housing to accommodate the substrate, in which the metal ring is electrically coupled to the system ground plane through a plurality of ground ends. The resonant cavity is formed between the system ground plane and the metal ring to generate a first resonant mode. The first and the second radiating portion are disposed on the second housing, for generating a second and a third resonant mode, respectively.

12 Claims, 5 Drawing Sheets



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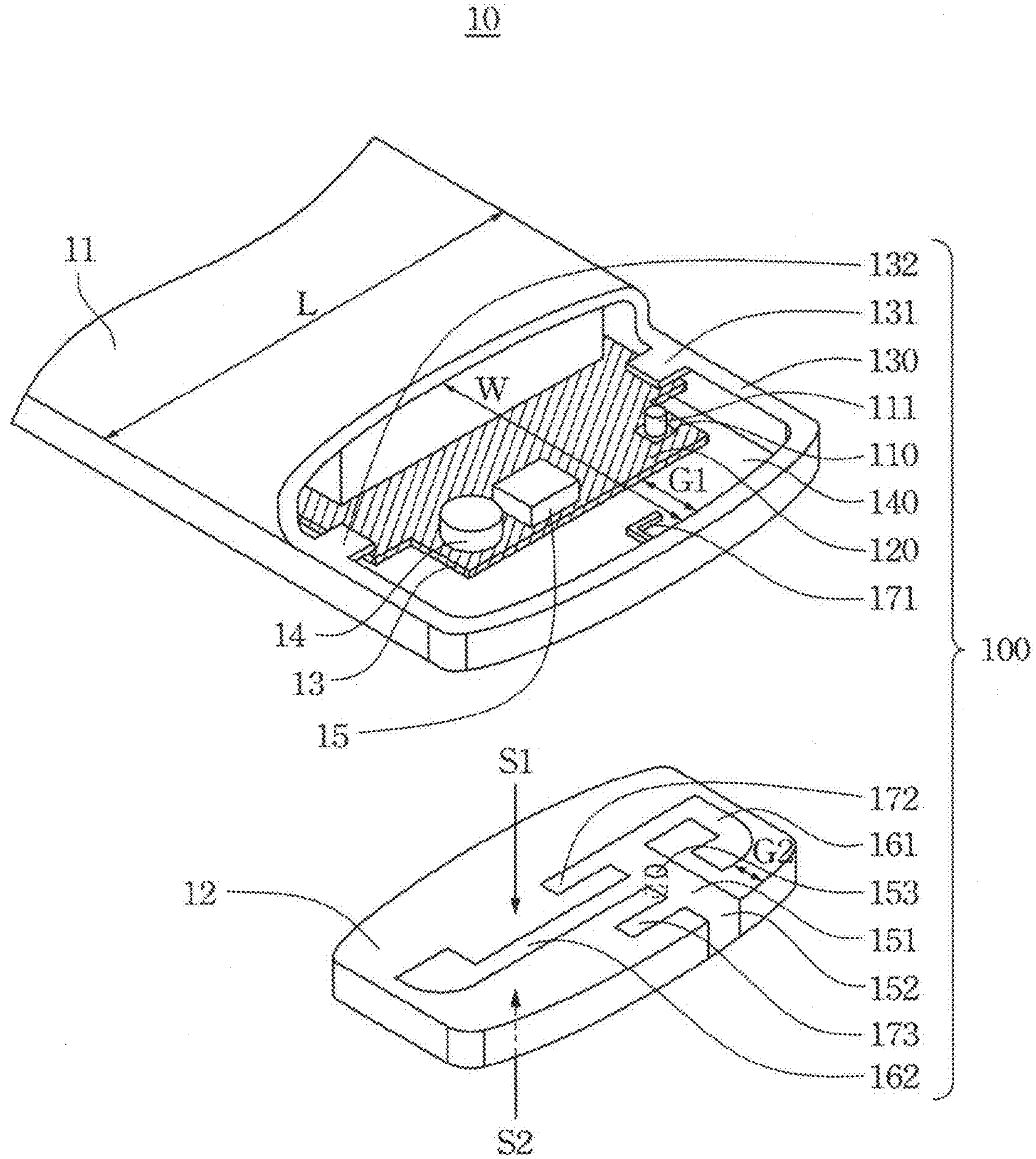
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Fig. 1

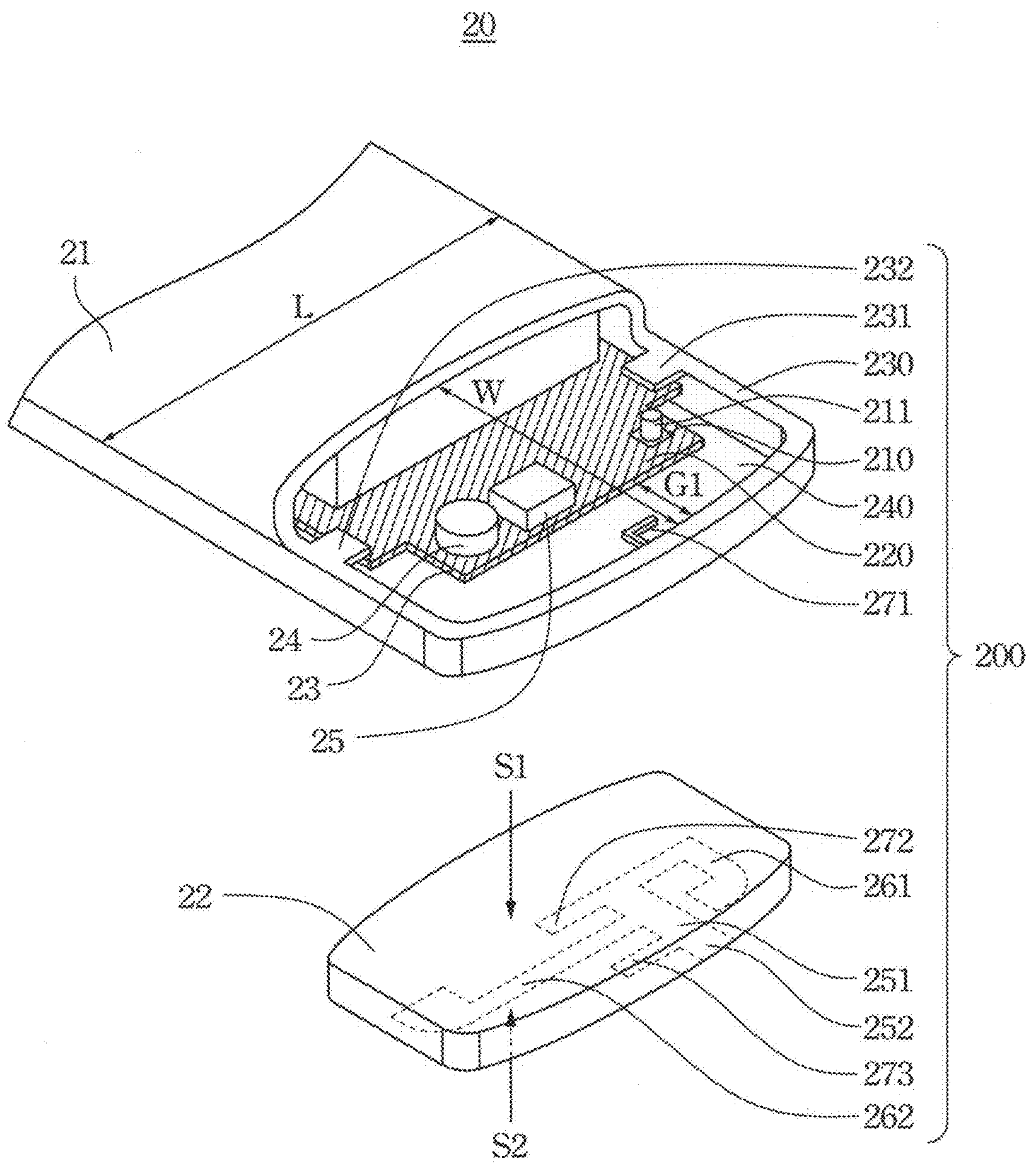
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Fig. 2

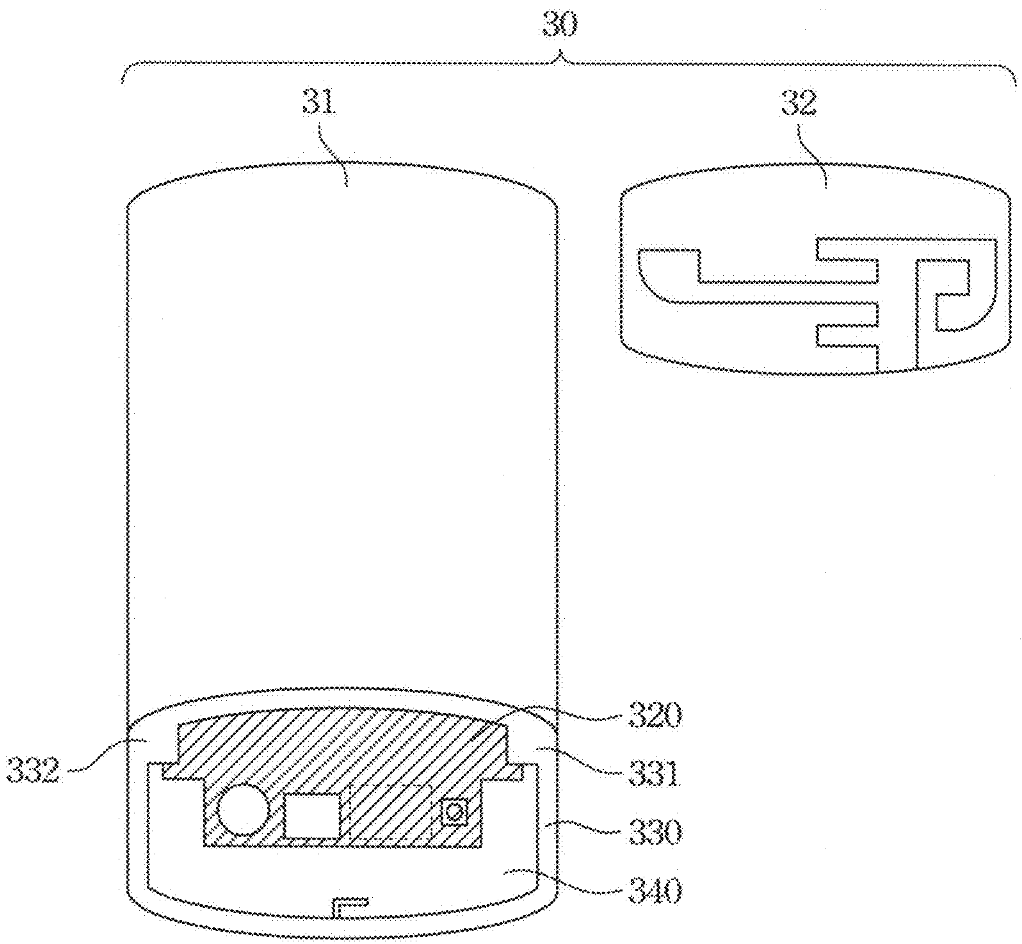


Fig. 3A

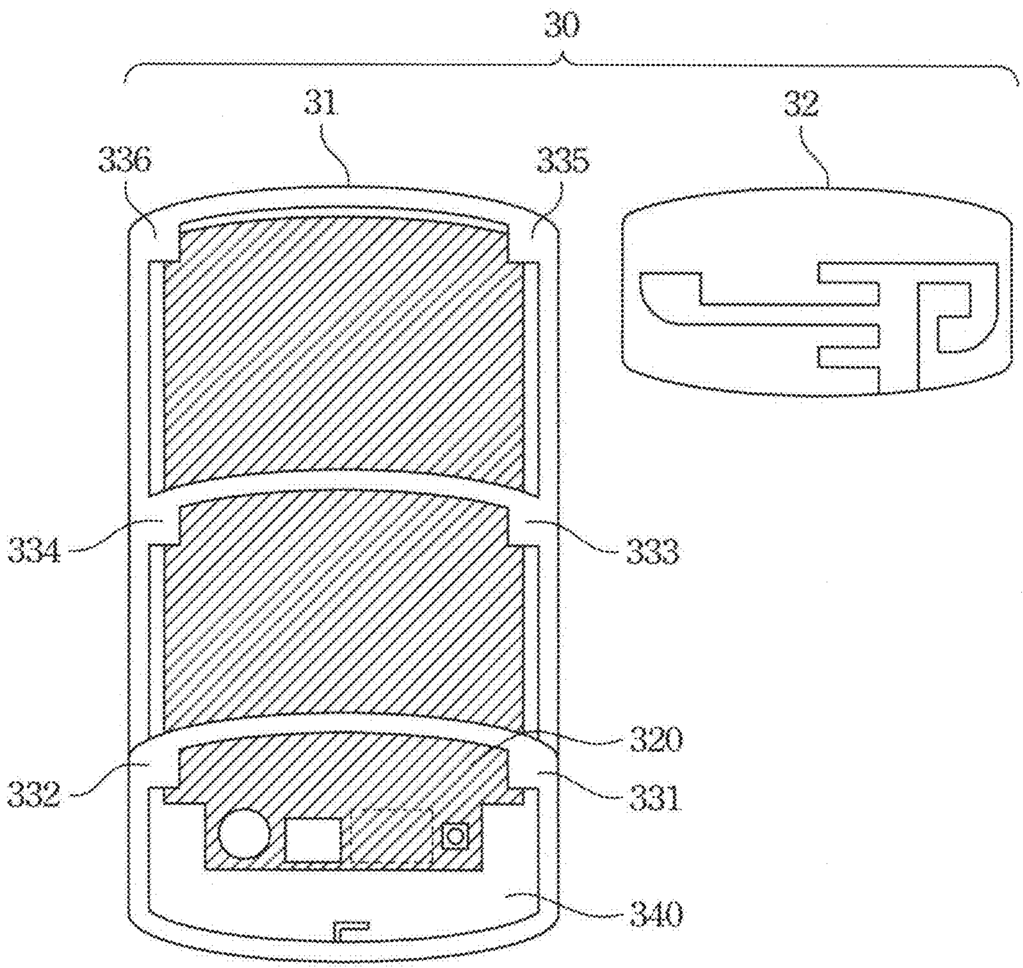
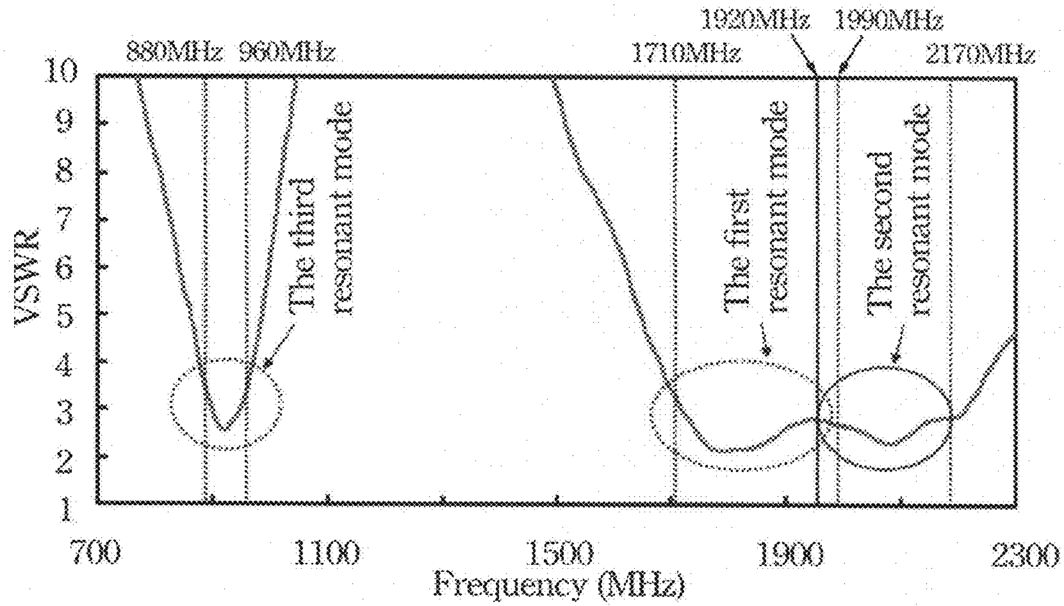
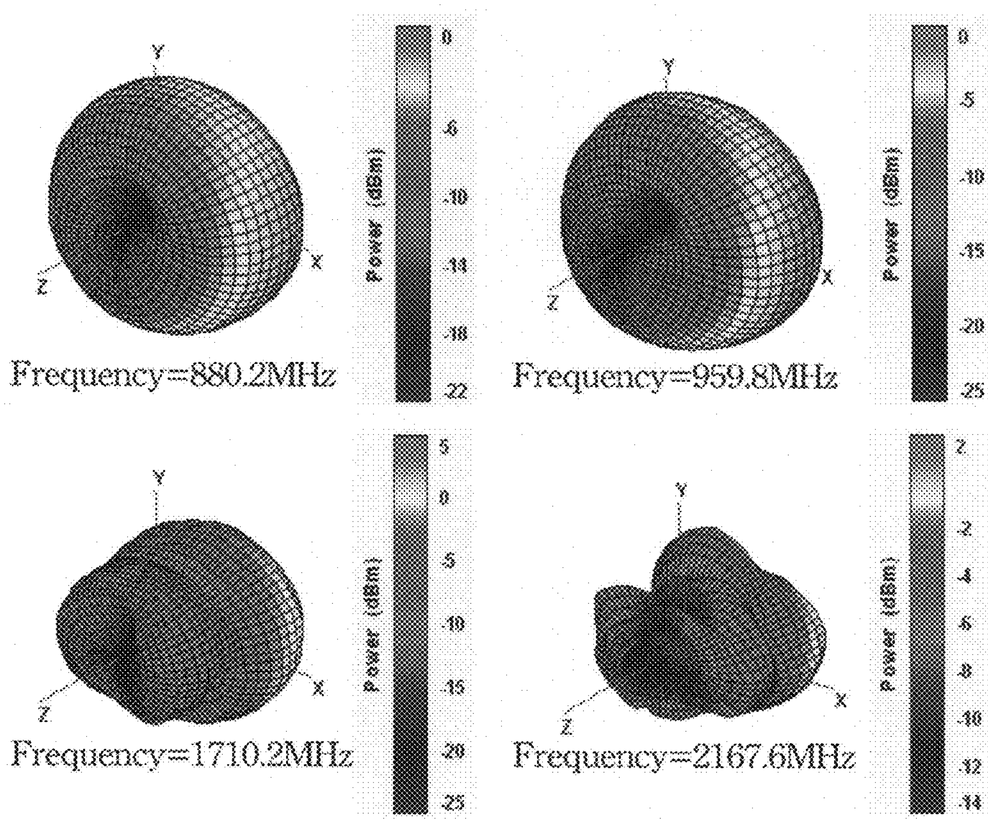


Fig. 3B



880MHz
960MHz
1710MHz
1920MHz
1990MHz
2170MHz
VSWR
10
9
8
7
6
5
4
3
2
1
The third resonant mode
The first resonant mode
The second resonant mode
700
1100
1500
1900
2300
Frequency (MHz)

Fig. 4



Frequency=880.2MHz
Frequency=959.8MHz
Frequency=1710.2MHz
Frequency=2167.6MHz
Power (dBm)

Fig. 5

MULTI-BAND ANTENNA FOR PORTABLE COMMUNICATION DEVICE

BACKGROUND

1. Field of Invention

The subject application relates to a multi-band antenna. More particularly, the subject application relates to a multi-band antenna for a portable communication device.

2. Description of Related Art

With various exterior designs of portable communication devices, portable communication devices having metal frames have become popular. Generally, in a design of an antenna for a portable communication device having a metal frame, the metal frame is cut into a plurality of discontinuous metal structures, so that the antenna can radiate radio frequency (RF) signals.

A conventional portable communication device utilizes a planar inverted-F antenna (PIFA) and a discontinuous metal frame to construct a multi-band antenna, such that requirements of lightness, thinness, short length, and small size of the portable communication device may be realized. However, constraints in the design of a multi-band antenna are encountered due to the spacing among an antenna main body, a system ground plane and the metal frame, increasing the difficulty of design. Moreover, this discontinuous metal structure may cause a frequency shift and radiation efficiency decline of resonant modes, thereby negatively affecting the communication quality of the portable communication device.

In view of foregoing, there is an urgent need in the related field to provide a solution.

SUMMARY

In one or more various aspects, the subject application is directed to a multi-band antenna for a portable communication device. The portable communication device includes a first housing, a second housing and a substrate. The multi-band antenna includes a feeding portion, a system ground plane, a metal ring, a resonant cavity, a first and a second radiating portion. The system ground plane is disposed on the substrate. The metal ring is connected to the first housing, and forms a space with the first housing to accommodate the substrate, in which the metal ring is electrically coupled to the system ground plane through a plurality of ground ends. The resonant cavity is formed between the system ground plane and the metal ring, and to generate a first resonant mode with the metal ring. The first and the second radiating portion are disposed on the second housing, for generating a second and a third resonant mode, respectively.

In accordance with an embodiment of the present disclosure, the foregoing multi-band antenna further includes a first conductive portion and a second conductive portion. The first conductive portion is disposed on the second housing, and the first radiating portion is electrically coupled to one side of the first conductive portion. The second radiating portion is electrically coupled to another side of the first conductive portion, and the first conductive portion is electrically coupled to the feeding portion when the first housing and the second housing are connected to each other. The second conductive portion is disposed on the second housing and electrically coupled to the first conductive portion, and the second conductive portion is electrically coupled to the metal ring when the first housing and the second housing are connected to each other. Furthermore, when the first housing and the second housing are connected to each other, a projection of the first conductive portion with respect to a normalized view of the substrate at least partially overlaps the resonant cavity.

In accordance with an embodiment of the present disclosure, a transverse dimension of the metal ring, a longitudinal dimension of the metal ring and a first gap width of the resonant cavity are used to control at least one of a resonant frequency of the first resonant mode, a bandwidth of the first resonant mode and a return loss of the first resonant mode.

In accordance with an embodiment of the present disclosure, the foregoing multi-band antenna further includes a first metal element disposed in the resonant cavity. An electrical length of the first metal element is used to adjust a current path and control a resonant frequency of the first resonant mode.

In accordance with an embodiment of the present disclosure, when an electrical length of the second radiating portion is longer than an electrical length of the first radiating portion, a resonant frequency of the third resonant mode is smaller than a resonant frequency of the second resonant mode.

In accordance with an embodiment of the present disclosure, when an electrical length of the second radiating portion is shorter than an electrical length of the first radiating portion, a resonant frequency of the third resonant mode is larger than a resonant frequency of the second resonant mode.

In accordance with an embodiment of the present disclosure, the foregoing multi-band antenna further comprises a second metal element and a third metal element, both of which are disposed on the second housing and electrically coupled to the first conductive portion. An electrical length of the second metal element is used to adjust an impedance matching of the first radiating portion, and an electrical length of the third metal element is used to adjust an impedance matching of the second radiating portion.

In accordance with an embodiment of the present disclosure, the feeding portion is disposed on the substrate and comprises a metal spring. The metal spring is electrically coupled to the first conductive portion when the first housing and the second housing are connected to each other.

In accordance with an embodiment of the present disclosure, the first conductive portion, the second conductive portion, the first radiating portion and the second radiating portion are disposed on a first surface of the second housing.

In accordance with an embodiment of the present disclosure, the foregoing multi-band antenna further includes a third conductive portion disposed on the second housing. The third conductive portion is electrically coupled to the first conductive portion and penetrates through the first surface and a second surface of the second housing. When the first housing and the second housing are connected to each other, the feeding portion is electrically coupled to the first conductive portion via the third conductive portion.

In accordance with an embodiment of the present disclosure, the first conductive portion, the second conductive portion, the first radiating and the second radiating are disposed on a second surface of the second housing.

In accordance with an embodiment of the present disclosure, the metal ring is a continuous metal structure.

In summary, through implementing the disclosure of the foregoing multi-band antenna structures, the bandwidth of resonant modes, antenna gain and performance of the portable communication device can be improved, and interference with the antenna caused by outside objects can be reduced. Therefore, high communication quality of the portable communication device is ensured.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject application can be more fully understood by reading the following detailed description of the embodiment, with reference made to the accompanying drawings as follows:

FIG. **1** is a perspective view of a portable communication device according to a first embodiment of the present invention;

FIG. **2** is a perspective view of a portable communication device according to a second embodiment of the present invention;

FIG. **3**A is a plan view of a portable communication device according to an embodiment of the present invention;

FIG. **3**B is another plan view of the portable communication device shown in FIG. **3**A;

FIG. **4** is a graph of a frequency response of a multi-band antenna for a portable communication device according to an embodiment of the present invention; and

FIG. **5** shows three-dimensional radiation patterns of a multi-band antenna for portable communication device according to an embodiment of the present invention.

DETAILED DESCRIPTION

In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to attain a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details. In other instances, well-known structures and devices are schematically shown in order to simplify the drawing.

FIG. **1** is a perspective view of a portable communication device **10** according to a first embodiment of the present invention. The portable communication device **10** can include at least a multi-band antenna **100**, a first housing **11**, a second housing **12**, a substrate **13**, a processor, a touch module, a display module, an input module, a power module and related electronic circuits (not shown). The multi-band antenna **100** can include a feeding portion **110**, a system ground plane **120**, a metal ring **130**, a resonant cavity **140**, a first radiating portion **161** and a second radiating portion **162**. The radiating portions **161** and **162** are used to generate resonant frequencies of a plurality of frequency bands. Furthermore, an exterior (appearance) of the portable communication device **10** can at least include the first housing **11**, the second housing **12**, the metal ring **130**, a bezel and/or an outer frame (not shown), etc, in which the metal ring **130** can be constructed as a portion of the housings **11**, **12** or a portion of the bezel and/or the outer frame.

In an embodiment of the present invention, the system ground plane **120** is disposed on the substrate **13**, the metal ring **130** is connected to the first housing **11** and cooperatively construct as a portion of the exterior (appearance), and the metal ring **130** and the first housing **11** cooperatively form a space to accommodate the substrate **13**, related electronic components (such as an electronic component **14** and an electronic component **15**) and related electronic circuits. In this manner, the metal ring **130** acts as a segment of the bezel and/or an outer frame, and can also be regarded as a portion of the exterior (appearance). Moreover, the metal ring **130** can be electrically coupled to the system ground plane **120** via a ground end **131** and a ground end **132**.

The resonant cavity **140** is formed between the system ground plane **120** and the metal ring **130** to construct a slot antenna with the metal ring **130** and generate a first resonant mode (or a first high-frequency mode), for example, an operating frequency band(s) of DCS-1800 and/or PCS-1900.

In this embodiment, a transverse dimension L of the metal ring **130**, a longitudinal dimension W of the metal ring **130** and a first gap width G1 of the resonant cavity **140** are used to control at least one of a resonant frequency of the first resonant mode, a bandwidth of the first resonant mode and a return loss of the first resonant mode. In practice, the transverse dimension L of the metal ring **130** can be 65 mm, the longitudinal dimension W of the metal ring **130** can be 16 mm and the first gap width G1 of the resonant cavity **140** can be 6 mm, in order to precisely control the resonant frequency (also known as the central operating frequency) of the first resonant mode within the operating frequency bands of DCS-1800 and PCS-1900, namely, between 1710 MHz and 1990 MHz.

In an embodiment of present invention, the multi-band antenna **100** further includes a first metal element **171**. The first metal element **171** is disposed inside the resonant cavity **140**, and may be electrically coupled to the system ground plane **120** via the metal ring **130**. The electrical length of the first metal element **171** is used to adjust a length of a current path for controlling the resonant frequency of the first resonant mode. For example, when the electrical length of the first metal element **171** is increased, the current path is lengthened, and accordingly the central operating frequency of the first resonant mode is decreased.

The first radiating portion **161** can be disposed on the second housing **12**. When the first housing **11** and the second housing **12** are connected to each other, the first radiating portion **161** can be electrically coupled to the feeding portion **110** for generating a second resonant mode. Similarly, the second radiating portion **162** can be disposed on the second housing **12**. When the first housing **11** and the second housing **12** are connected to each other, the second radiating portion **162** can be electrically coupled to the feeding portion **110**, for generating a third resonant mode.

In an embodiment of present invention, the multi-band antenna **100** further includes a first conductive portion **151** and a second conductive portion **152**. The first conductive portion **151** can be disposed on the second housing **12**. The first radiating portion **161** is electrically coupled to one side of the first conductive portion **151**, and the second radiating portion **162** is electrically coupled to another side of the first conductive portion **151**. When the first housing **11** and the second housing **12** are connected to each other, the first conductive portion **151** can be electrically coupled to the feeding portion **110**. The second conductive portion **152** can be disposed on the second housing **12** and electrically coupled to the first conductive portion **151**. When the first housing **11** and the second housing **12** are connected to each other, the second conductive portion **152** can be electrically coupled to the metal ring **130**.

In this embodiment, when the first housing **11** and the second housing **12** are connected to each other, a projection of the first conductive portion **151** with respect to the normalized view of the substrate **13** at least partially overlaps the resonant cavity **140**. In practice, the first conductive portion **151** and the resonant cavity **140** would not directly be connected with each other. It is partially with projection overlap from the view of the normalized plane.

In an embodiment of the presented invention, when the electrical length (or resonant path) of the second radiating portion **162** is longer than the electrical length of the first radiating portion **161**, the resonant frequency (also known as the central operating frequency) of the third resonant mode (or the first low frequency mode, e.g., GSM-900) is smaller than the resonant frequency of the second resonant mode (or the second high frequency mode, e.g., UMTS-2100). On the other hand, when the electrical length of the second radiating portion **162** is shorter than the electrical length of the first radiating portion **161**, the resonant frequency of the third resonant mode is larger than the resonant frequency of the second resonant mode.

In an embodiment of the present invention, the multi-band antenna **100** further includes a second metal element **172** and a third metal element **173**. Both of the metal elements **172**, **173** are disposed on the second housing **12** and electrically coupled to the first conductive portion **151**, in which the electrical length of the second metal element **172** is used to adjust an impedance matching of the first radiating portion **161**, and the electrical length of the third metal element **173** is used to adjust an impedance matching of the second radiating portion **162**. Therefore, by adjusting the electrical length of the second metal element **172**, at least one of the resonant frequency, the bandwidth and return loss of the second resonant mode can be controlled. Similarly, by adjusting the electrical length of the third metal element **173**, at least one of the resonant frequency, the bandwidth and return loss of the third resonant mode can be controlled. It is noted that the second metal element **172** and the third metal element **173** are not the essential elements of this embodiment, and a person skilled in the art can dispose related matching circuits on the substrate **13** to realize impedance matching, and this embodiment is not intended to limit the present invention.

In an embodiment of the present invention, the feeding portion **110** can be disposed on the substrate **13** and have a metal spring (or a pogo pin) **111**. When the first housing **11** and the second housing **12** are connected to each other, the metal spring **111** can be electrically coupled to the first conductive portion **151** for feeding an interior radio frequency (RF) signal, processed from an RF circuit (not shown) on the substrate **13**, to the feeding portion **110**, and then transmitting the signal to (a) the first radiating portion **161** and/or the second radiation portion **162**, and (b) the first conductive portion **151**, the second conductive portion **152** and the metal ring **130**. Similarly, an external RF signal can also be fed to the RF circuit and related electrical components on the substrate **13** via the same path, and an explanation of the operation in this regard will not be repeated herein.

In an embodiment of the present invention, the first conductive portion **151**, the second conductive portion **152**, the first radiation portion **161** and the second radiation portion **162** are disposed on a first surface S**1** of the second housing **12**. In addition, the multi-band antenna further includes a third conductive portion **153** disposed on the second housing **12**. The third conductive portion **153** is electrically coupled to the first conductive portion **151** and penetrates through the first surface S**1** and a second surface S**2** of the second housing **12**. When the first housing **11** and the second housing **12** are connected to each other, the feeding portion **110** is electrically coupled to the first conductive portion **151** via the third conductive portion **153**.

In an embodiment of the present invention, the metal ring **130** is a continuous metal structure. The structure of the bezel and/or outer frame of the portable communication device **10** is complete when the metal ring **130** is connected with the first housing **11**, so that the performance of the multi-band antenna is minimally interfered with by external objects. In addition, the first housing **11** can be constructed using metal or non-metal. In this embodiment, the electronic element **14** (e.g., a vibrator) and the electronic element **15** (e.g., a microphone) and related electronic circuits can be disposed on the substrate **13** without arranging slot(s), to utilize the space of the portable communication device **10** efficiently.

It is noted that when the first housing **11** and the second housing **12** are connected to each other, the feeding portion **110**, the first conductive portion **151**, the second conductive portion **152**, the third conductive portion **153**, the first radiating portion **161**, the second radiating portion **162**, the second metal element **172** and the third metal element **173** can form an overall structure of a PIFA. The PIFA can connect to the ground end **131** and the ground end **132** via the second conductive portion **152**, in which both the ground ends **131**, **132** are disposed on the metal ring **130**. All the parts of the PIFA can be formed using typical iron elements, copper foil, laser direct structuring (LDS) or by coating conducting liquid and/or paint, and perforation techniques may additionally be used. Furthermore, there is a second gap width G**2** between the first radiating portion **161** and an edge of the second housing **12**, and the second gap width G**2** can be adjusted to control at least one of the resonant frequency of the second resonant mode, the bandwidth of the second resonant mode and the return loss of the second resonant.

FIG. **4** is a graph of a frequency response of a multi-band antenna **100** for a portable communication device **10** according to an embodiment of the present invention. In the foregoing embodiments, the frequency response characteristic of the multi-band antenna **100** can be represented as the correlation between frequency and voltage standing wave ratio (VSWR), as shown in FIG. **4**. The VSWR of the multi-band antenna **100** is relatively small (i.e., VSWR<3) in the first resonant mode (1710 MHz~1990 MHz), the second resonant mode (1920 MHz~2170 MHz) and the third resonant mode (824 MHz~960 MHz), such that the portable communication device **10** can operate under the operating frequency bands of DCS-1800 and/or PCS-1900, UMTS-2100 and GSM corresponding to these three resonant modes.

FIG. **5** shows three-dimensional radiation patterns of a multi-band antenna **100** for a portable communication device **10** according to an embodiment of the present invention. In the foregoing embodiment, antenna gain and radiation efficiency of the multi-band antenna **100** can be represented as a three-dimensional radiation pattern and antenna performance information corresponding to the pattern, as shown in FIG. **5** and Table. 1.

TABLE 1

Frequency (MHz)	Efficiency (dB)	Efficiency (%)
880.2	−4.1	39.1
881.6	−4.1	39.1
893.8	−3.4	45.8
897.6	−3.2	47.4
914.8	−2.7	53.6
925.2	−2.9	51.6
942.6	−3.5	44.9
959.8	−4.4	36.6
1710.2	−2.7	53.5
1747.8	−2.8	52.5
1784.8	−2.4	57.1
1805.2	−2.1	61.8
1842.6	−2.0	63.6
1850.2	−2.0	62.7
1879.8	−2.1	62.2
1880	−2.1	62.2
1909.8	−2.2	60.5
1922.4	−2.1	61.3
1930.2	−2.0	62.8
1950	−1.9	64.9
1960	−1.9	64.1
1977.8	−2.1	61.3
1989.8	−2.3	58.3
2112.4	−3.4	45.3
2140	−3.5	44.4
2167.6	−3.3	47.1

For example, within the frequency band of the first resonant mode DCS-1800/PCS-1900 and the second resonant mode UMTS-2100, namely 1710 MHz~2170 MHz, the radiation efficiency of the first multi-band antenna **100** is larger than 44%. On the other hand, within the frequency band of the third resonant mode GSM-900, namely 880 MHz~960 MHz, the radiation efficiency of the first multi-band antenna **100** is larger than 36%.

FIG. **2** is a perspective view of a portable communication device **20** according to a second embodiment of the present invention. The portable communication device **20** at least includes a multi-band antenna **200**, a first housing **21**, a second housing **22**, substrate **23** and related modules and electronic circuit elements (not shown). As in the case of the above embodiment, the multi-band antenna **200** can include a feeding portion **210**, a system ground plane **220**, a metal ring **230**, a resonant cavity **240**, a first conductive portion **251**, a second conductive portion **252**, a first radiating portion **261** and a second radiating portion **262**. The structure and operation of the multi-band antenna **200** are similar to or the same as those of the multi-band antenna **100** of the portable communication device **10** described with reference to FIG. **1**, and therefore, a description in this regard will not be repeated herein.

In an embodiment of the present invention, the first conductive portion **251**, the second conductive portion **252**, the first radiating portion **261** and the second radiating portion **262** are disposed on the second surface S2 of the second housing **22**. Therefore, when the first housing **21** and the second housing **22** are connected to each other, the feeding portion **210** can be directly electrically coupled to the first conductive portion **251** for feeding RF signals, without having to go through the third conductive portion **153** as shown in FIG. **1**.

FIG. **3**A and FIG. **3**B are plan views of a portable communication device **30** according to an embodiment of the present invention. The portable communication device **30** includes a multi-band antenna, a first housing **31**, a second housing **32** and a substrate **33**. In this embodiment, the structure and operation of the multi-band antenna are similar to or the same as those of the foregoing embodiment, and so a description in this regard will not be repeated herein. When the first housing **31** is a non-metal frame structure, there is an arc shaped metal connection between a ground end **331** and a ground end **332** so that a metal ring **330** and a resonant cavity **340** can form a slot antenna, as shown in FIG. **3**A. It is noted that when the first housing **31** is a metal frame structure, the metal ring **330** can be electrically coupled to a system ground plane **320** not only via the ground end **331** and the ground end **332**, but also via other ground ends (namely, ground ends **333~336**), as shown in FIG. **3**B, and the subject application is not limited to this structure, deployment and connection type.

In summary, through implementing the features of the subject application, a multi-band antenna with slot antenna(s) and PIFA(s) can be constructed and the space inside the portable communication device can be increased. Moreover, the interference caused by external objects can be reduced by deploying a continuous metal ring. Therefore, the bandwidth, the antenna gain, and the antenna radiation efficiency of the portable communication device can be improved, and the communication quality of the portable communication device is ensured.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims.

What is claimed is:

1. A multi-band antenna for a portable communication device, the portable communication device comprising a first housing, a second housing and a substrate, and the multi-band antenna comprising:

a feeding portion;

a system ground plane disposed on the substrate;

a metal ring directly connected to the first housing, the metal ring and the first housing cooperatively forming a space to accommodate the substrate, wherein the metal ring is electrically coupled to the system ground plane through a plurality of ground ends;

a resonant cavity formed between the system ground plane and the metal ring, and to generate a first resonant mode with the metal ring;

a first radiating portion disposed on the second housing, the first radiating portion being operatively and electrically coupled to the feeding portion, wherein the first radiating portion is electrically coupled to the feeding portion for generating a first resonant mode when the first housing and the second housing are connected to each other, and the first radiating portion is isolated from the feeding portion and does not generate the first resonant mode when the first housing and the second housing are separated from each other; and

a second radiating portion disposed on the second housing, the second radiating portion being operatively and electrically coupled to the feeding portion, wherein the second radiating portion is electrically coupled to the feeding portion for generating a second resonant mode when the first housing and the second housing are connected to each other, and the second radiating portion is isolated from the feeding portion and does not generate the second resonant mode when the first housing and the second housing are separated from each other;

wherein the first housing comprises an opening, and the second housing is configured to be operatively attached to the opening of the first housing to cooperatively form an exterior housing of the portable communication device.

2. The multi-band antenna of claim **1**, further comprising:

a first conductive portion disposed on the second housing, wherein the first radiating portion is electrically coupled to one side of the first conductive portion, the second radiating portion is electrically coupled to anther side of the first conductive portion, and the first conductive portion is electrically coupled to the feeding portion when the first housing and the second housing are connected to each other; and

a second conductive portion disposed on the second housing and electrically coupled to the first conductive portion, wherein the second conductive portion is electrically coupled to the metal ring when the first housing and the second housing are connected to each other;

wherein, when the first housing and the second housing are connected to each other, a projection of the first conductive portion with respect to a normalized view of the substrate at least partially overlaps the resonant cavity.

3. The multi-band antenna of claim **1**, wherein a transverse dimension of the metal ring, a longitudinal dimension of the metal ring and a first gap width of the resonant cavity are used to control at least one of a resonant frequency of the first resonant mode, a bandwidth of the first resonant mode and a return loss of the first resonant mode.

4. The multi-band antenna of claim **1**, further comprising: a first metal element disposed in the resonant cavity, an electrical length of the first metal element adjusting a current path and controlling a resonant frequency of the first resonant mode.

5. The multi-band antenna of claim **1**, wherein when an electrical length of the second radiating portion is longer than an electrical length of the first radiating portion, a resonant frequency of the third resonant mode is smaller than a resonant frequency of the second resonant mode.

6. The multi-band antenna of claim **1**, wherein when an electrical length of the second radiating portion is shorter than an electrical length of the first radiating portion, a resonant frequency of the third resonant mode is larger than a resonant frequency of the second resonant mode.

7. The multi-band antenna of claim **2**, further comprising a second metal element and a third metal element, both disposed on the second housing and electrically coupled to the first conductive portion, wherein an electrical length of the second metal element is used to adjust an impedance matching of the first radiating portion, and an electrical length of the third metal element is used to adjust an impedance matching of the second radiating portion.

8. The multi-band antenna of claim **2**, wherein the feeding portion is disposed on the substrate, the feeding portion comprises a metal spring, and the metal spring is electrically coupled to the first conductive portion when the first housing and the second housing are connected to each other.

9. The multi-band antenna of claim **2**, wherein the first conductive portion, the second conductive portion, the first radiating portion and the second radiating portion are disposed on a first surface of the second housing.

10. The multi-band antenna of claim **9**, further comprising a third conductive portion disposed on the second housing, the third conductive portion being electrically coupled to the first conductive portion and penetrating through the first surface and a second surface of the second housing, wherein when the first housing and the second housing are connected to each other, the feeding portion is electrically coupled to the first conductive portion via the third conductive portion.

11. The multi-band antenna of claim **2**, wherein the first conductive portion, the second conductive portion, the first radiating and the second radiating portions are disposed on a second surface of the second housing.

12. The multi-band antenna of claim **1**, wherein the metal ring is a continuous metal structure.

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